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SPECIFIC GRAVITY AND COMPOSITION OF POTATOES FOR VARIOUS PROCESSING AND COOKING PURPOSES[1]

MARY V. ZAEHRINGER, *Chairman*,[2] ROGER M. REEVE,[3] EUGENE A. TALLEY,[4] DONALD H. DINKEL[5] AND R. B. HYDE[6]

The optimal compositional factors for the culinary and processing requirements of potatoes depend in large measure upon the manner of processing and the kind of processed product involved. In general, both the growing and the commercial processing phases of the potato industry have emphasized disease resistance, yield, maturity, specific gravity or total solids, and external tuber characteristics. Somewhat less attention has been given to the internal chemical composition which markedly affects the culinary and processing quality. Of major importance are the characteristics of the tuber that affect texture, color, and flavor. Obviously, one set of attributes will not satisfy all requirements.

In the three major classes of commercially processed products — dehydrated products, chips, and French fries — high solids content and a dry, mealy texture are desired. However, the textural qualities desired for other processed potato products may not always be obtainable with high specific gravity potatoes because high solids content and predisposition to heavy sloughing usually occur simultaneously. These qualities are unsuitable for products where firm piece form is desired.

Color is also a very readily discernible quality. The optimum color (in the United States and Canada at least) for steamed, boiled, baked, or mashed potatoes is a creamy white. For fried products, a light, uniform golden crust is considered optimum. Off-color is usually associated with after-cooking darkening of fresh tubers or with the undesirable darkening from the non-enzymatic browning (Maillard) reaction that may occur during frying or dehydrating. For optimum color, low reducing sugar content is desirable, especially for chips and French fries.

The optimum flavor in a potato product is a mild natural potato flavor with no off-flavors. Certain compositional factors influence natural flavor and its retention, especially in processed products. Other factors influence the development of off-flavors although neither phenomenon is thoroughly understood at present. While the assessment of off-flavors is mostly categorized by organoleptic evaluation, the development of improved objective chemical methods could well contribute to a better

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[2]Home Economist and Head, Home Economics Research, Agricultural Experiment Station, College of Agriculture, University of Idaho, Moscow, Idaho 83843.

[3]Histologist, Potato Investigations, Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Albany, California 94710.

[4]Chemist, Potato and Other Vegetable Investigations, Eastern Utilization Research and Development Division, Agricultural Research Service, U. D. Department of Agriculture, Philadelphia, Pennsylvania 19118.

[5]Horticulturist, Department of Horticulture, Iowa State University, Ames, Iowa 50010.

[6]Head, Food Technology, British Columbia Institute of Technology, Burnaby 2, British Columbia.

understanding of the many factors involved.

The committee has found no reports of studies starting with composition of the raw tuber and carried through to an extensive quality evaluation of the cooked or processed product. However, a number of investigations have been reported concerning certain factors in the raw product which affect selected quality characteristics important in cooking or processing. Few of the articles deal directly with the subject of "optimum" characteristics, most being based upon an implied desirable condition or characteristic. This report summarizes recent work in the area. Earlier work has been summarized in several reviews (2, 14, 38, 43).

TEXTURE

The direct relationship between high specific gravity and a dry, mealy texture has received further confirmation (27, 29, 31, 42, 52). In a comprehensive investigation relating composition to texture, mealiness was found to be positively correlated with total solids, starch, alcohol-insoluble solids, alkalinity of the ash, total potassium, and alcohol-insoluble potassium (29). These constituents as well as specific gravity were also found to be correlated with the amount of sloughing (29, 30, 48, 51). Decreases in sloughing after soaking thin slices of potato tissue in distilled water appeared to be related to the amount of potassium, magnesium, phosphorus, and citric acid lost to the soak water (7). Phytin appears to be a factor in the separation of cells after cooking in old potatoes but not in new potatoes (46). More sloughing was observed in canned potatoes when specific gravity was greater than 1.082 than when it was 1.082 or less (48). The absence of sloughing in some high specific gravity potatoes was considered the result of a high nitrogen content in the outer layers of tuber tissues (40). The nitrogen was assumed to have been derived from coagulated albumin which toughened the outer layer of the cooked tubers. Texture in potatoes that had been stored was related to changes in insoluble nitrogen and the synthesis of protein (5). A higher content of insoluble pectins and hemicelluloses was found in "hard" cooking potatoes than was found in "soft" cooking potatoes (39).

A study of potato starch (a major factor in textural quality) indicated that "the fundamental properties are determined essentially by the size of the (starch) granules" (9). Amylose content and gelation temperature, so important to textural qualities of processed products, were both directly related to starch granule size.

COLOR

Potato chips from tubers of high specific gravity were lighter in color than chips from tubers of low specific gravity (22, 33). However, high specific gravity does not always insure good color in chips (35). A possible explanation for these conflicting findings may be found in a more recent report which indicates that the two characters of specific gravity and chip color rating are inherited independently (6).

Sucrose, glucose, fructose, and total reducing substances were negatively correlated with light chip color (4, 18, 19, 21, 37, 45). Maximum glucose concentration for good chip color was 0.2% (37). However, if more than 3% sucrose was present, even a glucose content of less than 0.3% was reported to result in dark colored chips. The darker color of chips prepared from CIPC-treated tubers was ascribed to the slightly higher reducing sugar content resulting from the lack of sprout growth (8). Reducing sugar levels of 0.2% to 0.3% were considered to be essential for French fries (26).

Browning of potato chips is apparently affected in some way by phosphorus (10, 11, 12). A large amount of radiophosphorus was directly correlated with light color in most cases and the chips were dark in color if the concentration of radiophosphorus was low. High levels of potassium fertilization resulted in less reducing and total sugars in the tuber and produced lighter colored chips than low levels of potassium fertilization (12). Potatoes fertilized with KCl almost always produced lighter-colored chips than K_2SO_4-fertilized potatoes. Tubers containing high concentrations of manganese, zinc, and copper generally produced dark colored chips (19). High total (Calgon-soluble plus hydrochloric acid-soluble) calcium content of raw tubers was correlated with light colored chips and low fat absorption (35).

A positive relationship was reported between specific gravity and after-cooking darkening of Katahdin potatoes (32). After-cooking darkening in steamed potatoes was associated with the content of chlorogenic acid (23, 24, 25). Only small amounts were detected in freshly harvested potatoes, but steamed potatoes contained ten times as much. Chlorogenic acid was synthesized in tubers rapidly on the breaking of dormancy (36) and also increased significantly during storage at 40 F but not at 60 F (13). The increase in chlorogenic acid during cold storage was considered due to the accumulation of reducing sugars. Caffeic acid disappears when potatoes begin to sprout (36). After-cooking blackening was significantly correlated with low levels of citric, orthophosphoric, and oxalic acids (16). This was more pronounced at the stem than at the bud end of the tubers. Citric acid was considered the most important acid in preventing blackening and chlorogenic acid the most important in causing it (20).

After-cooking discoloration was positively correlated with the concentration of iron in potato tubers (17, 24, 25) and negatively correlated with potassium content (15). Autoradiographs of radioiron distribution in tubers showed that areas of highest radioiron corresponded to areas showing after-cooking darkening (49, 50). The degree of discoloration was reported to depend on water and oxygen content and to be intensified by a high pH (24). The correlation coefficient for "protein iron" was greater than that for "free iron" (17). Protein from the stem end contained significantly more iron than protein from the bud end (17). Boron foliar sprays inhibited after-cooking darkening (34). No association was observed between blackening of cooked potato tissue and quinic acid content (23) or chloride content (44) of tuber tissue.

No correlations were found between the gray color in potatoes submersed in milk and the content of dry matter, alcohol-insoluble solids, monosaccharides, or disaccharides (47).

FLAVOR

Specific gravity of fresh tubers had no effect on equilibrium moisture isotherms (a measurement useful in studies of storage stability) of flakes prepared from them (41).

Sulfhydryl groups and their role in natural flavor of potatoes may be influenced by potato phosphorylase (28). Since off-flavor development in stored potato granules is related to the degree of autoxidation of the unsaturated fatty acids (3) and unsaturated acids are oxidized at a more rapid rate than saturated acids, any increase in the content of unsaturated fatty acids could be expected to shorten the storage life of this type of processed product. Boron foliar sprays increased total lipids and phospholipids in three varieties (34) and unsaturated fatty acids tended to increase whereas the saturated acids tended to decrease. The cortex had a higher lipid content than the center tissue of the tuber. Exposure to light increased solanine content of potato tubers and decreased cooking quality (1). Flavor changes during storage were associated with variations in the concentration of proteins and insoluble nitrogen (5).

The committee's work for this year points up the need for additional and comprehensive studies to develop a body of knowledge about the raw product which could be used to predict the quality of the cooked or processed product. Research of this type should yield valuable basic information and could be used to great advantage by the potato industry. The committee considers the following areas particularly worthy of attention:

1. Improved accuracy in the quick estimation of solids either by specific gravity or other means.
2. Extensive investigations concerning composition of tuber tissue especially in relation to variety, growing conditions, etc.
3. Breeding experiments designed to develop potato varieties of different amylose-amylopectin ratios for exploratory processing application.
4. Improving high solids varieties to improve textural qualities of dehydrated products, chips, and French fries.
5. Development of more all-purpose varieties and varieties suitable for more specialized purposes.
6. Effect of temperature and period of storage on changes in ascorbic acid content, sugar composition, and specific gravity.
7. A survey of the potato processing industry to determine characteristics desired in the raw potatoes for various processed products and which of these characteristics can be controlled or altered in the processing procedures.

In addition there is a real need for more complete and more rapid abstracting of foreign literature on potato processing.

The committee hopes that research in the future on these and related subjects may be conducted along much closer lines of cooperation among potato breeders, processing technologists, publicly supported institutions, and industry than has been possible for the past several decades.

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